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A New License Plate Recognition System Based on Probabilistic Neural Networks

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Abstract

A license plate recognition system employs image processing techniques, to help to identify the vehicles through their plates. License plate recognition is a process, where first the license plate region is localized in a car image supplied by one camera or by multiple cameras, and then the characters on the plate are identified by a character recognition system. There are many applications of the license plate recognition systems, both public and private. The algorithms, hardware and the network structure for recognition are designed according to the specific application. Recently, thanks to the advances in science and technology, the algorithms and hardware of higher quality have been designed, and license plate recognition systems are now widely used. The recognition can be done in three major steps: Localization of the plate, extraction of the plate characters, and recognition of the characters using a suitable identification method. In this paper, an algorithm is designed that can recognize plates using the pictures taken at various angles, various distances and different times of the day, thus under various illumination conditions. The plate is localized using Otsu's thresholding method and the plate features. Vertical and horizontal histograms are used for character segmentation. Finally, character recognition is done by Probabilistic Neural Networks. Simulation results are included and performance analyses are tabulated. MATLAB program is used in the simulations.

Keywords: License plate recognition; character recognition; neural networks; probabilistic neural networks; image processing

1. Introduction

License plate recognition has many applications such as in traffic flow control, automatic parking systems, automatic bridge systems, and radar based speed control. The advantage of the license plate recognition system is its ability to operate without the need to install extra equipment on the car.

A license plate recognition system has basically three modules for:

a) Localization of the plate region using the image of the car,
b) Extraction of the characters, and
c) Recognition of the characters using a suitable algorithm.

In this work, a new algorithm has been developed to recognize the plates under varying illumination, distance and skew conditions. The regions of a given car image, where the license plate might be found, are determined using Otsu's thresholding method. Then the plate features are used to detect the real plate region. Later, column sum vector (CSV) calculations are performed to implement the character extraction. Those characters are recognized using a Probabilistic Neural Network (PNN). MATLAB program is used in the simulations.

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Some of the previous work in the literature is summarized in the rest of this section.

El-Adawi, Keshk and Haragi have designed an automatic license plate recognition system based on Neural Networks that were trained using back propagation algorithm. They have obtained 89% success rate for license plate extraction and 93% success rate for character recognition of the extracted plates [1].

Emiris and Koulouriotis have combined training and recognition of alphanumeric characters to use in a semi-structured environment. They have tabulated the success rates for the recognition of letter A under various conditions, the averages for the success rates turned out to in the range of 59-77.4% [2].

Juntanasub and Surreerattanan have worked on two-level Thai plate system. They have employed off-line Hausdorff Distance technique for similarity measurement, and thus for recognition. They have obtained 92% success rate in plate recognition [3].

Rattanathammawat and Chalidabhongse have worked on plate localization problem. They have employed Sobel edge detector, moving-window plate localizer and a temporal analyzer for false detection suppression. The success rate for correct detection of plates was 94% [4].

Raus and Kreft have utilized Neural Networks, both in detection and character recognition. They have compared their method with the classical approaches and found out that theirs was superior [5].

Sirithinaphong and Chamnongthai have utilized Motor Vehicle Regulation to train their four-layer back propagation Neural Network. They have obtained 84.29% success rate for the plate localization and 80% success rate for the character recognition [6].

Park, Kim, Jung and Kim have used Neural Networks for plate localization. They have tested their networks on two sets of data and the success rates for localization were 97.5 and 99% [7]

Kim, Kim, Kim and Kim segmented the plates by Neural Networks and recognized the characters by Support Vector Machines. Their segmentation rate was 97.5%, and character recognition rate was 97.2% [8].

Jianfeng, Shaofa and Zhibin have worked on Chinese car plate system. They have employed a Neural Network for color analysis for correct plate extraction. Their success rate was 95.7% [9].

Broumandia and Fathy have used Neural Networks to recognize Farsi plates. They have obtained an average of 95% success rate in plate recognition [10].

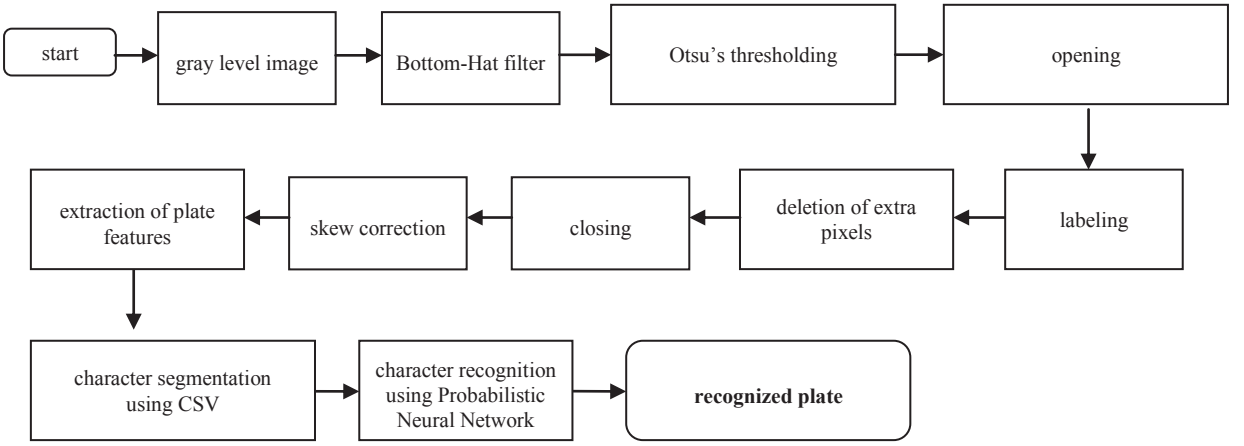
Ganapathy and Lui have utilized feed-forward back propagation Neural Networks in character recognition. Their success rate was 95% [11].

2. The Probabilistic Neural Network Approach for License Plate Recognition

The algorithm works on the gray level image. The image in question is converted to its gray levels to begin with. Then some preprocessing techniques are applied on the gray level image. Those are Bottom-Hat filtering, Otsu's thresholding, opening, labeling, closing, correction of the skew, and extraction of the rectangular regions which can possibly contain the plate. Then the plate features are used to determine the correct plate region. Column sum vector (CSV) charts are used for character segmentation. Finally the characters are recognized using a Probabilistic Neural Network. The flowchart of the algorithm is shown in Fig. 1.

Bottom-Hat filtering is used to enhance the potential plate regions. Thresholding is employed for binarization of the gray level image, and thus to separate the object of interest from the background. Due to environmental factors, brightness levels may vary and some adaptation is necessary. Otsu's thresholding technique is used because of its adaptive nature. The segments of the binary images are labeled according to their color to enable classification. The plate extraction is done calculating the CSV and its local minima. The local minima should be compared to a threshold value. They are used for determining the alphanumeric characters.

The characters that are differentiated by the character extraction module are isolated and saved in memory. The dimensions of the characters are equalized and a template matching algorithm is used. The correlation of each extracted character and each template in the database is calculated. The segmented characters are smoothed and the critical points at the boundaries are calculated.



3. Simulation Results

The database used for this work consists of 260 photos of cars. The dimensions of each photo are fixed and are 384*288 mm. Those photos are captured at various times of the day, from various distances and at various angles. Some examples taken from the database are shown in Fig. 2.

Fig. 2. Samples from the car image database.

Reduction to gray levels, filtering and thresholding are done as the preprocessing. Reduction to gray levels is done for the elimination of the unnecessary information in the color image. This way, the speed of the processing increases tremendously. An example is shown in Fig. 3.

Fig. 3. (a) original picture; (b) gray level image

The localization of the plate is the first and the most important step. If it fails, the rest definitely fails. The potential plate regions are evaluated on the basis of features, such as aspect ratios, and the number of pixels, and then the correct one is identified. Column sum vectors are used to determine the boundaries of the characters in the feature extraction step. An algorithm has been developed to separate two adjacent characters and to unify characters that were split into two. Finally the obtained characters are recognized using a Probabilistic Neural Network. The characters obtained from the images in the database are used as a training set and this set is used to train the Neural Network.

The Bottom-Hat filter is applied to the gray level image, to enhance the potential plate regions. After Otsu's thresholding, opening is applied to delete the small areas that cannot belong to a character. Then labeling and

closing are applied successively. Finally, the skew is corrected. The resulting images of each step for a sample image from the database are shown in Fig. 4.

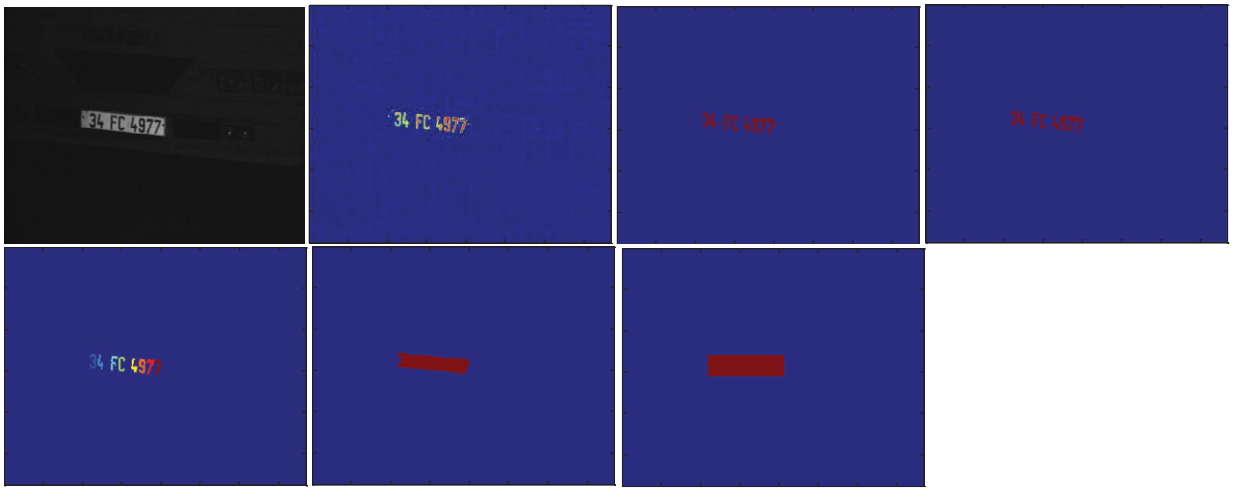


Fig. 4. (a) gray level image; (b) Bottom-Hat filter; (c) Otsu's thresholding; (d) opening; (e) labeling; (f) closing; (g) skew correction

If more than one candidate plate regions are obtained, then the selection is based on the plate features. Those are:

- Plate height should be at least 12 pixels,
- Plate width should be at least 16 pixels,
- Plate height should be at most 1/8th of the image,
- Plate width should be at most 1/3rd of the image,
- Plate area should be at most 1/4th of the total area.

The obtained plate region for the example, the corresponding CSV chart and the extracted characters are shown in Fig. 5. A character lies in between two local minima in the CSV chart. The segmented characters are detailed in Fig. 6. Another example of the plate region and the segmented characters are shown in Fig 7.

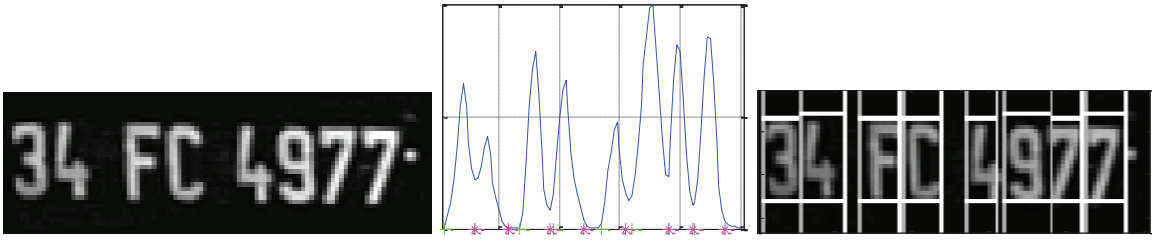


Fig. 5. (a) extracted plate region; (b) corresponding CSV chart; (c) segmented characters

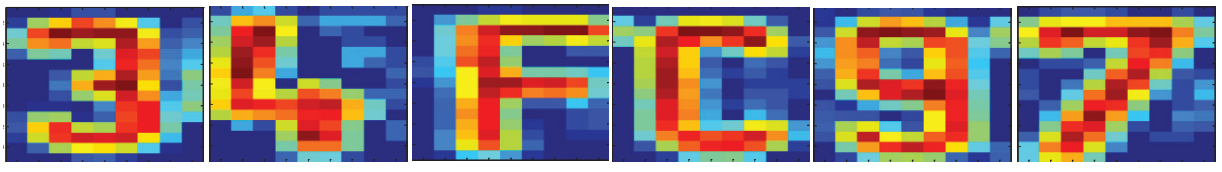


Fig. 6. Segmented characters of the example

Fig. 7. Second example (a) extracted plate region; (b) segmented characters

The extracted characters are fed in to the Probabilistic Neural Network. The outputs are the recognized characters.

4. Conclusion

The program needs an average of 0.1 seconds on Intel® Core™2 Duo Processor CPU P8400 (2.26GHz, 2267 MHz) computer to recognize each plate. The simulation results are evaluated on the basis of both plate and character recognition. The calculations are summarized in Table 1.

Table 1. Summary of the results

Item	Amount	Success rate
Number of correct plate regions	256	98.5%
Number of correct plate recognitions	233	91%
Total number of plates	260	
Number of correct character recognitions	1914	96.5%
Total number of characters	1984	

A plate is not recognized correctly, even if a single character is in error. Therefore, character recognition is in the center of plate recognition. The increase in the success rate of the character recognition module can boost further the success rate of the plate recognition. In the future, the research will continue in this direction.

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